

# Lessons from SimCalc: What research says

## Research Note 6

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*SimCalc is a promising model for teaching mathematics in a technology-facilitated environment. At the heart of the model is the use of technology to integrate graphical, dynamic and linguistic representation to enhance student learning. At Texas Instruments, we see implications that extend far beyond the project and are important to the entire graphing calculator and classroom networking community in math and science education.*

For over a decade, researchers of the SimCalc Project, based at the James J. Kaput Center for Research and Innovation in Mathematics Education at the University of Massachusetts, Dartmouth, have been striving to fulfill their vision of “democratizing access” to important, advanced mathematics. To this team, democratizing access has meant two things: (1) enabling children from all backgrounds to learn conceptually-rich mathematics and (2) scaling up to demonstrate measurable impact throughout whole districts, regions, and states.

A core belief of the project is that technology can provide a new representational and connectivity infrastructure for teaching and learning. Coupled with the right curriculum, teacher professional development, and school leadership, this infrastructure can make advanced concepts—including those usually addressed only in an elite Calculus course—accessible to many more students and at earlier grade levels. The SimCalc instructional approach emphasizes developing multiple, interrelated mathematical fluencies including both procedural and conceptual (declarative) understandings. For more information on the SimCalc Project, its software and pedagogy see <http://www.simcalc.umassd.edu>.

Research evidence of effectiveness of this model is strong, and includes a series of successful tests of the SimCalc approach in a broad range of schools with the full range of contexts and student ability levels. This range of evidence is important because it demonstrates the broad power of the approach. For example, a recent large-scale randomized controlled trial conducted in Texas middle schools produced large effects (Roschelle, et al, 2007). The study reports:

The overall effect size was 0.84,  $t(93) = 9.1$ ,  $P < 0.0001$ ), using a two-level hierarchical linear model with students nested within teacher. The difference between the SimCalc and control groups occurred mostly on the complex portion of the test. The effect size of treatment on this portion was 1.22 ( $t(93) = 10.0$ ,  $P < 0.0001$ ). The effect size of the treatment on the simple portion was 0.17 ( $t(93) = 1.8$ ,  $P < 0.072$ , n.s.); many students had mastered these concepts before the unit began... Randomized controlled trials of this scale support the strongest causal inferences, yet are rarely conducted in education... These results support claims (a) that the SimCalc approach was effective in a wide variety of Texas classrooms, (b) that teachers successfully used these materials with a modest investment in training, and (c) that student learning gains were robust despite variation in gender, ethnicity, poverty, and prior achievement.

The SimCalc Project at the University of Massachusetts, Dartmouth and the independent evaluation team at SRI International are conducting extensive additional research. Additional data is being collected in the second year of a 7<sup>th</sup> grade study to look at the effect of ongoing professional development on the impact of technology in student learning. A parallel 8<sup>th</sup> grade study is examining the impact of the SimCalc approach in the learning of linear functions, again across many regions of Texas. A pilot study in Singapore is exploring the extension of these findings internationally.

The SimCalc Project is significant to the entire community of educators using TI graphing calculators and classroom networking technology, at every level and in every math and science curriculum, whether or not they choose to use the SimCalc tools and curricula. The project continues to yield both valuable curricula and professional development, and important lessons on how to improve mathematics teaching and learning. Among the most important implications for instruction are:

- *Multiple, Dynamically Linked Representations.* Math and science have evolved a variety of visual, verbal and symbolic systems for representation of their core principles. SimCalc illustrates the power of linking these representations dynamically, so that students can see how one representation changes when others do. This not only builds deep understanding, but it helps overcome the inabilities of any single representation

system to show important aspects of the principle being taught – especially dynamic aspects. It also builds connections between principles and concepts which are often taught in isolation (sometimes years apart, in conventional curricula). The ability to move easily across a connected network of knowledge, and to change representation systems, is critical to high-level problem- solving when doing “real” mathematics and science.

- *Direct Visual Manipulation of Models and Simulations.* Connecting representations to students’ real-world knowledge requires use of contextualized models and simulations. When students can directly manipulate them visually (e.g., by dragging curves or objects), they can observe the dynamic operation of the principles underlying the model or simulation, especially when a full suite of “hot links” to multiple representations of these principles are present.
- *Collaborative Learning Facilitated by Classroom Networks.* When teachers use classroom networks to provide immediate feedback, and to facilitate exploration, prediction and explanation, student engagement dramatically increases. TI’s research on the Model Districts program confirms that this effect has been shown to be powerful, with students of all ability levels, and preliminary research suggests that it sustains over the whole school year and beyond. The SimCalc Project has investigated how students can discover links across representations from working locally with SimCalc MathWorlds™ on their TI graphing calculator to discussing links between their contributions when aggregated and displayed at the public level.
- *Communication, Reflection and Revision.* The technology acts as a tool which can facilitate an ongoing process of communication, reflection on reasoning, and frequent revision of work. Because of the ease of changing work products, the focus no longer has to be on completing a static worksheet or assignment without error. Instead, the focus can turn toward a continuous process of investigation with evolving representations which trace the building of understanding. In addition to improved learning processes, this creates new options for formative and summative assessment.
- *Participation, Engagement and Motivation.* Students can participate in mathematically meaningful ways through the combination of dynamic, interactive executable representations and classroom networks. These new forms of participation frameworks have shown to impact students’ motivation to engage in mathematical reasoning, and conceptual analysis through new forms of expression that lead to positive learning outcomes.

SimCalc MathWorlds™ is available as a cross-platform software, and with support from Texas Instruments, this team has deployed SimCalc representations and connectivity on widely available, robust and inexpensive TI graphing calculators and networks, increasing the opportunities to reach large numbers of teachers and students.

#### References:

Jeremy Roschelle<sup>1</sup>, Deborah Tatar<sup>2</sup>, Nicole Shechtman<sup>1</sup>, Stephen Hegedus<sup>3</sup>, Bill Hopkins<sup>4</sup>, Jennifer Knudsen<sup>1</sup>, Antoinette Stroter (2006) “Can a Technology-Enhanced Curriculum Improve Student Learning of Important Mathematics?” Available from the SimCalc Web site, <http://www.simcalc.umassd.edu>.